IMPROVED MEASUREMENT SYSTEM

FOR

SO_2 DRY DEPOSITION RATES

Alberta
ENVIRONMENT
Pollution Control Division
Air Quality Control Branch

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ABSTRACT

A system to measure SO2 dry deposition rates by an atmospheric flux method has been developed. A flame photometric SO2 monitor with sensitivity enhancement by SF6 addition is used to measure concentrations at two levels. Temperature difference is monitored between these levels using thermocouples. A reversing apparatus reduces or eliminates the systematic errors in temperatures. A sonic anemometer is used to measure the covariance of temperature and vertical velocity. The eddy diffusivity for heat is calculated from the ratio of the covariance to the potential temperature gradient. The SO2 deposition rate is then estimated from the product of the eddy diffusivity and the SO2 concentration gradient. Most calculations are performed in real time using a Campbell Scientific CR7 measurement and control system. Field trials of the apparatus were performed over ripe barley during August 1983 near Crossfield, Alberta. Results indicate SO2 deposition velocities of approximately 0.1 cm/s in the evening and 1.0 cm/s during morning daylight hours.

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1.0 INTRODUCTION

During the past three years, an improved system for providing SO2 flux measurements has been developed by Promet Environmental Group Ltd. in conjunction with Concord Scientific Ltd.

Initially, a literature review of dry deposition measurement techniques was made and an assessment of their applicability and reliability, especially under field conditions was completed (Phase I). Following this review, a workshop was held in Edmonton in 1981. The consensus of workshop participants preferred direct flux measurements over mass balance and surface accumulation methods.

A final report outlining the various measurement techniques was presented to Alberta Environment in 1981 (Hunt et al). The latter two methods were discarded because of their inability to measure the transport mechanisms responsible for SO2 fluxes directly. Moreover, the uptake of SO2 with these methods cannot be correlated with environmental or biological conditions of the canopy except on time scales in excess of hours. The establishment of this relationship between ambient levels of SO2 and its removal by an agricultural crop was the ultimate objective of this study.

The flux technique favoured by the report involved eddy correlation measurements between SO2 and vertical winds. Direct measurement of SO2 laden eddies was not possible at that time because the SO2 analyzer response was too slow relative to the eddies transporting SO2.

Eddy accumulation measurements were the second-rated preferrence. The inability to capture low SO2 concentrations without sample bag absorption effects ruled them out, however.

Direct SO2 gradient measurements were made during the following year in a field setting (Phase II). Concord Scientific participated in the Inter Comparison Dry Deposition field trials conducted by the U.S. Environmental Protection Agency at Champagne, Illinois. Using an enhanced flame photometric detection (FPD) Meloy SO2 analyzer, estimates of SO2 concentrations were made at four heights above ground. Flux calculations used micrometeorological data measured by other participants in the field trial. There were a number of equipment, weather, data interpretation and field problems, however. Preliminary data only are available at this time and a final report from Concord Scientific is pending.

The third and final phase of the project was carried out by Promet in 1983. Following an equipment and information exchange workshop involving Concord, Promet and Alberta Environment, instrumentation and sampling modifications and improvements were implemented to prepare for a summer field trial in Alberta.

2.0 THEORY

Estimates of SO2 fluxes can be produced using the following equation:

$$F = K(z) \frac{(SO2\ (z2) - SO2\ (z1))}{z2 - z1}$$

where F = flux density or quantity of SO2 transferred to the surface per unit area per unit time

K(z) = eddy diffusivity constant at height z (in m2/s)

SO2(z) = mean SO2 concentration for a specified averaging period at height z (in ug/m3)

z = height in m

z1 = height of sampling level #1

z2 = height of sampling level #2

The transport mechanism for SO2 is deemed to be analogous to that for water vapor or heat fluxes in most atmospheric conditions where turbulent eddies are the dominant means of transport. Heat flux measurements were chosen for the Phase II and III field trials because of the success other researchers had experienced in using fast response sensors such as sonic anemometers.

The following expression shows how K(z) was computed:

$$K(z) = \frac{Z\ (\overline{W'T'})}{(\Delta T + \Gamma \Delta Z)}$$

where $\overline{W'T'}$ is the covariance of vertical wind and temperature. That is, the average of the product of the deviations from the means of vertical velocity and temperature.

ΔT is temperature difference over difference of height ΔZ.

Γ is the dry adiabatic lapse rate.

The deposition velocity is an empirical parameter which is used to estimate SO2 fluxes from the ambient SO2 concentrations.

Estimates of the deposition velocity (Vd) were computed using the following equation:

$$Vd = F/C$$

where C is the mean of the two average SO2 concentrations measured at z2 and z1, respectively.

3.0 INSTRUMENTATION-SENSORS

There were ten variables recorded continuously in our field experiment. These included:

1) incoming solar radiation
2) horizontal wind at 10 m elevation above the ground
3) temperature difference over between 0.5 and 3.5 m above the crop canopy
4) vertical winds at 2 m above crop canopy
5) air temperature a 2 m above crop canopy
6) ambient SO2 concentration at the same heights over which the temperature difference is measured
7) temperature in the crop
8) relative humidity in the crop
9) wind speed at the crop canopy (approximately 1 m above ground)

A 10 m tower was used to mount the sensors for items 1-6. A Li Cor pyranometer generated data which included both solar and sky radiation data. Windflo 540 transducers were used to measure both 10 m and crop canopy wind speed and direction. Copper-constantan thermocouple junctions provided a temperature difference measurement over the 3 m interval above the crop canopy.

A special reversing arm mechanism was built to rotate every 15 minutes to help remove systematic errors associated with the thermocouple sensors. Although based on an original design published by Black (1971), reversing psychrometric arm improvements were made by Promet. For example, since a 115 VAC power supply was available, a reversing motor with worm gear drive was used to prevent the booms from over or under shooting because of strong winds. Moreover, special radiation shields were constructed under the direction of T. Gillespie (personal communication) of the University of Guelph. The design will be discussed in the section covering system improvements.

A Campbell Scientific sonic anemometer with a fine thermocouple junction (0.01 mm) constructed from chromel-constantan was used for generation of heat flux and eddy correlation data. The sensing arm was mounted 2 m above the crop facing the southeast. The fine thermocouple wire measures the temperature fluctuations between itself and a reference junction housed inside the anemometer's "thermal mass".

A Meloy SA260 FPD analyzer enhanced with SF6 provided the SO2 concentration measurements. The enhancement provided a lower detection limit of 0.2 ug/m^3 SO2 (0.1 ppb). Two sample lines constructed from 1/4" TFE teflon were used to transport continuous air samples under the vacuum of a GAST diaphragm pump. Inverted glass funnels over the sample inlets kept out all rainfall. The sample lines were mounted on the northwest side of the tower which faced the SO2 source. The sample lines were wrapped with heat tracing to prevent condensation and the lines were placed inside a wide diameter flexible conduit. Teflon solenoid valves were used to alternate between the two sample heights which were actually 0.5 and 3.5 m above the crop canopy.

Ambient temperature and relative humidity were monitored inside the crop at 0.5 m. A Stevenson Screen without a stand was used to house the Campbell Scientific 207 probe.

An 8'x16' trailer was used to shelter the non-sensing components of the monitoring system in a temperature controlled environment.

4.0 DATALOGGER FUNCTION AND PROGRAMMING OVERVIEW

Datalogging and sampling system control were performed using the Campbell Scientific CR7 datalogger. Data were recorded on a tape recorder for further processing, besides being logged by a printer. While all input processing was done for 15 minute periods, varied scan rates were used for each of the three output tables that were produced by the CR7. For the sonic anemometer, a scan rate of 10 per second was used in addition to a subaveraging period of 180 seconds. The subaveraging interval, which is included in the Campbell eddy correlation software, acts like a high pass filter by instructing the CR7 not to correlate any incoming signals with frequencies over three minutes.

The SO2 analyzer output signal was sampled every second although a time delay was introduced following valve switching to allow SO2 equilibrium to be reached in the sample lines. The CR7 controlled the sample valve closure and an attendant selection of sample height. The valves were opened and closed by the CR7 every 15 seconds but only the last five seconds of SO2 readings were used in the calculations by the CR7. The Meloy SO2 analyzer attained 96 percent of the response in 10 seconds on the chart recorder. In reality, the response is probably faster since the chart recorder is limited by the pen movement speed.

Fifteen minute averages of SO2 concentration were computed for each of the two sampling heights. The Meloy SO2 analyzer burner block and detector temperatures were monitored to determine if the equipment was in the recommended operating range.

The third output table computed by the CR7 generated the other variables. A 10 second scan rate was used to create 15 minute averages for relative humidity, temperature, 10 m wind speed and directions, temperature difference above the canopy and solar radiation. Differential temperatures were monitored only after the lapse of a five minute sensor equilibrating period following the boom reversal. The CR7 controlled the timing of the boom reversal in a fashion similar to that of the solenoid valves. The ten metre winds were recorded as vector quantities.

A Soltec chart recorder was used to back up the CR7 recording of the SO2 analyzer measurements.

5.0 SITE SELECTION

Site requirements for the field trial included the following (in order of importance):

1) near a large source of SO2 (i.e. a sour gas plant)
2) downwind location during daylight hours
3) uniform and flat topography at least between the source and sampling site
4) healthy and growing agricultural crop available as SO2 sink above which measurements would be taken
5) landowner concurrence
6) line power available
7) road access available

All of the above conditions were met with exception of item (6). As a result, two gas driven power generators were employed - one for the air conditioner and the second for everything else. A line conditioner was used to smooth out any transients which could cause harm to the voltage sensitive components.

The selected field trial site was located downwind from the Amoco Canada Petroleum Ltd. East Crossfield gas plant, which is a licensed source of 37.2 tonnes of sulphur daily. Figure 1 shows the location of the field trials in relation to the Amoco plant and other local topographical features.

Records from the Calgary International Airport indicated the 30 year normal prevailing wind direction to be from the north-northwest during the growing season. A year long study using minisonde balloon flights in 1979-80 conducted by Promet for Amoco indicated a persistent northwesterly flow at plume level during daylight hours.

The terrain to the south-southeast of the plant is a plain rising gently towards highway #2. The ground cover was a crop of spring barley.

The location chosen for the program was approximately 800 m to the southsoutheast of the Amoco gas plant stacks. There was a gas burner and associated pipeline heater station to the southeast of the field trial site. The power generators and associated fuel storage were situated to the east of the trailer.

Petrogas Processing Ltd. operates a sour gas plant 22 km to the southeast of the monitoring location and releases approximately 16 tonnes of sulphur daily to the atmosphere.

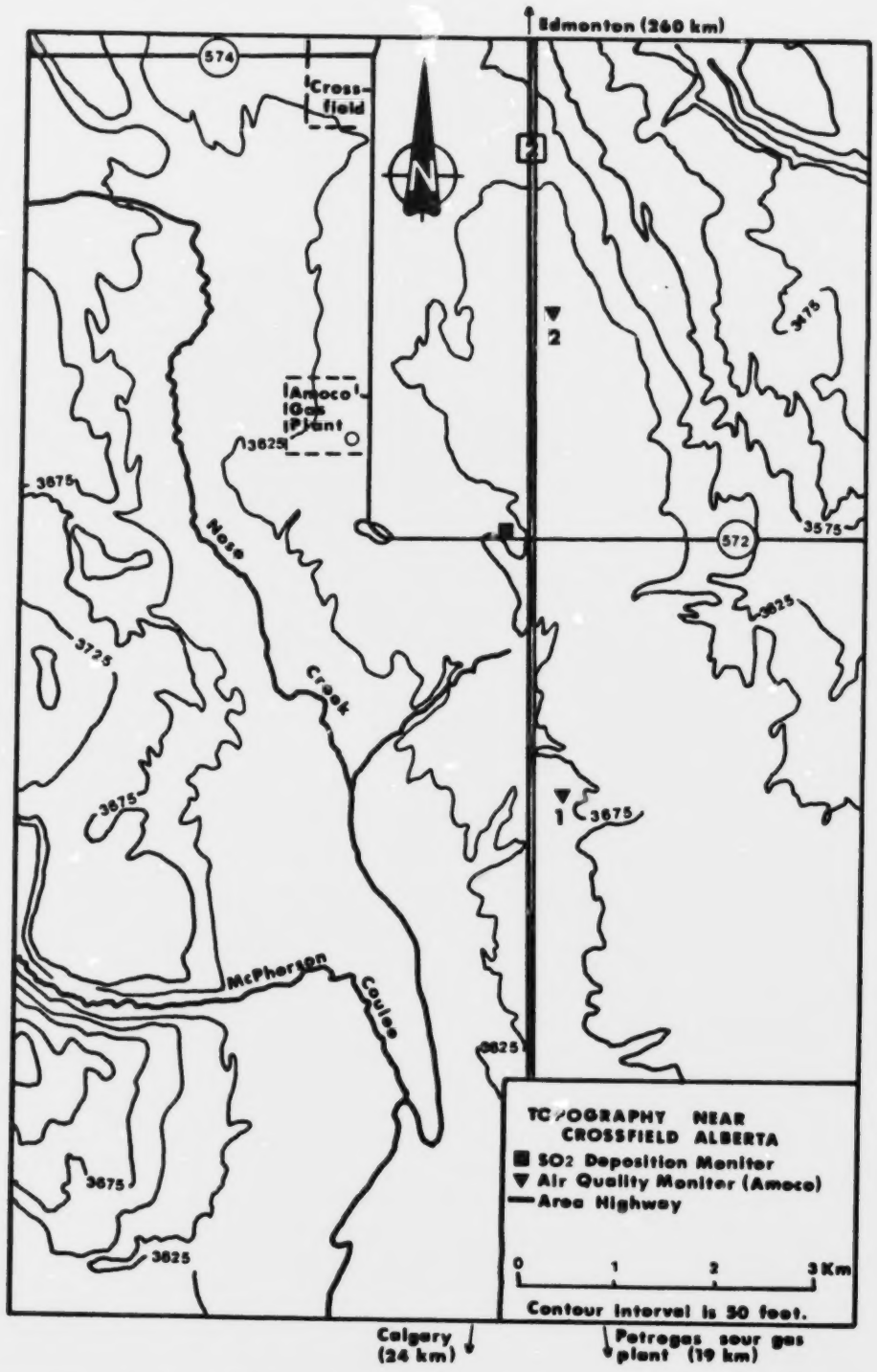

Figure 1. Crossfield topographical map.

6.0 INSTRUMENTATION IMPROVEMENTS

A number of improvements were implemented to the air quality sampling instrumentation, datalogging, micrometeorological sensors, and calibration techniques. These four categories are discussed in detail below.

6.1 AIR QUALITY SAMPLING INSTRUMENTATION

The Meloy SA260 SO2 analyzer displayed erratic signals and serious drift problems when first used by Promet. Subsequent repairs included burner cleaning and realignment, a new photomultiplier tube and thermistor in the detector oven temperature control circuit. While it was in the shop, a linearizing card was added to convert the non-linear output to a linear scale.

All stainless steel fittings used in the sampling system were replaced with their TFE teflon counterparts to improve the absorption characteristics. Acting on the recommendation of Concord Scientific, only two sampling heights were used for SO2 instead of the previous four. Glass funnels were installed over the sample line inlets to prevent the introduction of precipitation inside the lines.

The flow of air inside the sample lines was monitored with the addition of rotameters to the sample manifold. Switching between SO2 sampling heights was controlled automatically by the CR7 datalogger and a relay driver. Concord Scientific, while switching the solenoid valves manually, had to overlap the selected sampling heights to ensure a continuous flow of air to the Meloy, to prevent the extinguishing of the flame. The CR7 datalogger switched the two way valves instantaneously, thereby removing the need for any sampling overlap.

6.2 DATALOGGING

A sophisticated datalogger was used to measure and record, in the field, all meteorological variables required for the equations given earlier. There are several advantages to employing a suitable datalogger: 1) By using optimum scan rates and appropriate statistical routines for presenting data, many of the errors associated with data abstraction from charts and inherent recording problems were removed. 2) By allowing an appropriate equilibration period before recording SO2

concentrations following valve switchover or differential temperature after arm reversal, extraneous data are ignored and left out of the calculations. 3) The use of a slower sampling integration time (16.7 ms) while measuring SO2 concentrations smoothed out high frequency noise associated with the analyzer electronics. 4) All eddy correlation and gradient computations were performed in the field providing prompt data access to the user. Traditionally, data are transferred to a large computing system and computer programs are required to reduce the data to a useable format. 5) Both SO2 analyzer temperature control circuits were monitored for deviations as these can influence the amount of drift in the analyzer response. Linearizing software in the datalogger converted both burner block and detector oven analog signals to temperature values directly. In this fashion, analyzer performance and stability were monitored continuously.

6.3 MICROMETEOROLOGICAL INSTRUMENTATION

The sonic anemometer used for measurement of turbulent eddies and direct calculation of the eddy diffusion constant, K(z), replaces the traditional multi level anemometry. Fewer sensors on the tower reduce the frequency of maintenance and lessen the chance for downtime associated with sensor breakdowns.

The temperature difference apparatus featured three distinct improvements over an earlier design by Black et al (1971). First, radiation shields were constructed, under the guidance of T. Gillespie, to protect the temperature sensing elements from direct radiative effects and conductive influences. Figure 2 shows a cutaway view of the radiation shield assembly.

The surfaces beneath the highly reflective outer shell are painted either flat black or white in an optimal sequential fashion to disperse any remaining conductive or radiative heat effects. Black surfaces are used to absorb and radiate heat energy while white surfaces reflect heat readily. Ventilation holes in the PVC inner cylinder are used to allow any heated air to excape before it reaches the thermocouple junction. A transistor heat sink was used to center the thermocouple junction in the middle of the ventilation airstream.

Second, as noted earlier a reversing worm gear motor was used to prevent any additional forward or reverse motion beyond the 90 degree upright location. Third, a rubber sleeve was used to couple the motor and arm to prevent any excessive motor torque when the power was turned off.

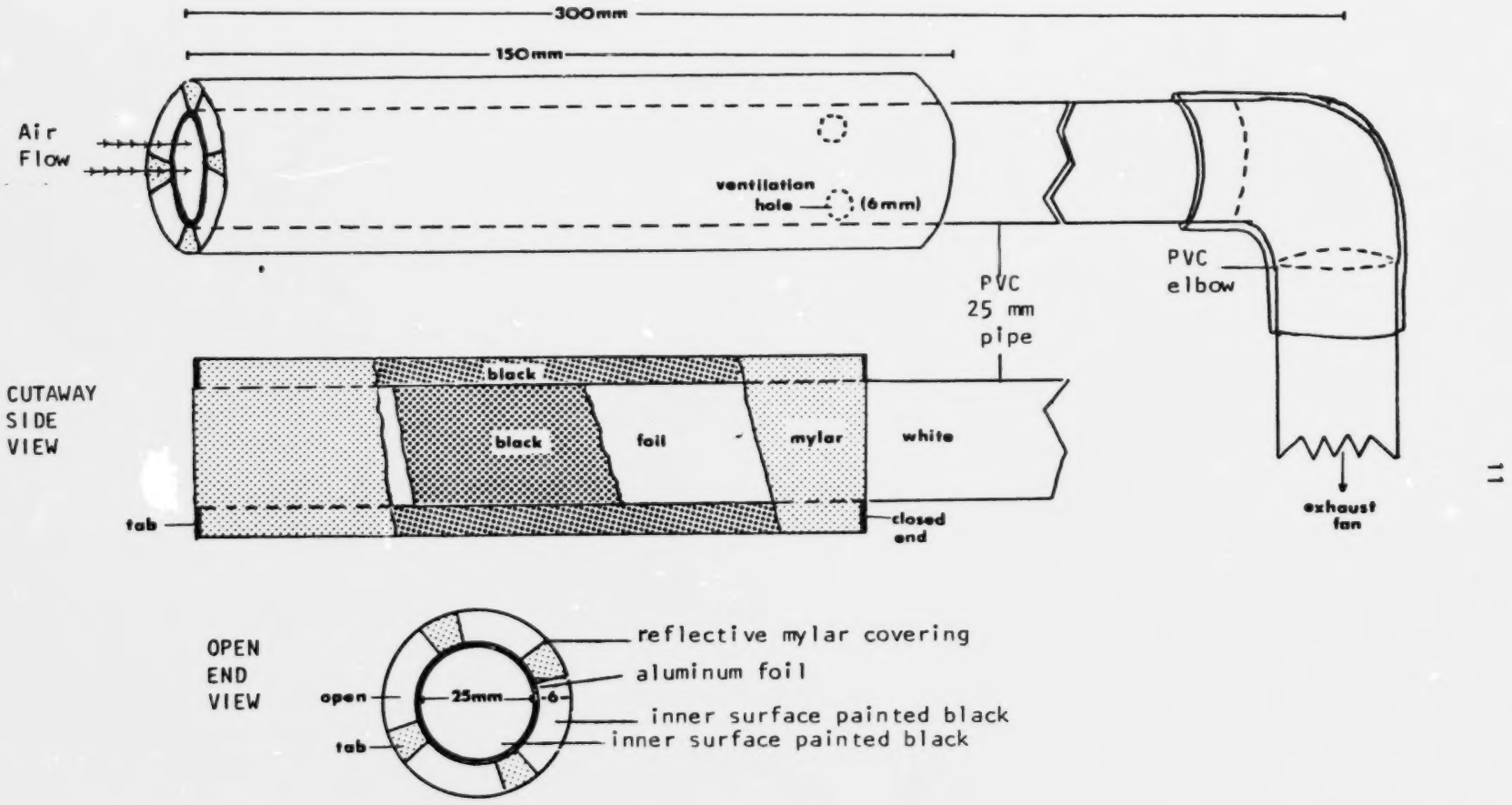

Figure 2. Schematic of the radiation shield assembly.

6.4 CALIBRATION TECHNIQUES

Multipoint calibrations were performed on the analyzer using a technique which was traceable to a National Bureau of Standards reference. A permeation tube in a temperature controlled oven purged with several diluting flows of SO2 free air providing concentrations between 131-390 ug/m^3 (44-134 ppb) were used initially. However, an extended concentration range of 65-570 ug/m^3 (25-219 ppb) was used for the last three days of calibration.

One of the challenges in carrying out multipoint calibrations is to provide a very low, stable SO2 concentration. Ambient SO2 concentrations are less than 20 ug/m^3 (8 ppb) more than half the time. To confirm the linearity of the analyzer some of the calibration points should be within this range. The lowest SO2 reference concentration attainable in this work was 65 ug/m^3 (25 ppb). Lower levels of SO2 can be reached by a two stage dilution.

In order to determine the relationship between analyzer response and SO2 calibration gas concentrations, estimates were made using one and two parameter linear regression and a power law. Linear regression with two parameters was discarded because it gave large negative intercepts. The power law technique does provide a better fit of the analyzer response to the standard concentrations at low SO2 concentrations than linear regression with a fixed origin. Standard error values, given in Table 1 show consistently lower values using power law approximations to the calibration curves. Confidence intervals for concentrations in the range between zero concentration and the lowest calibration point were generally smaller for interpolations by the power law.

Line conditioning with air containing no SO2 and air containing SO2 with a concentration of 210 ug/m^3 (80 ppb) was tried and abandoned after determination of its minimal effect on sampling accuracy.

Table 1. Comparison of linear regression (fixed origin) and power law approximations to Meloy calibration curves. Units are millivolts. Linear regression general equation is $(SO2) = MR$ whereas power law general equation is $(SO2) = AR^B$ where R is the analyzer response.

Date	SO2 Concentration (ug/m3)										Linear Regression		Power Law		
	65.0	98.7	131.0	155.8	191.0	201.9	204.2	262.5	389.9	569.9	M	S.E.	A	B	S.E.
8/8			48.8		65.1			88.6	124.5		3.03	13.2	1.532	1.149	3.2
10/8			49.2		66.4			88.7	127.3		2.98	11.6	1.294	1.187	1.9
11/8			49.9		67.4			87.4	121.6		3.06	18.6	1.107	1.222	1.5
12/8	Calibration Data Lost														
13/8			51.3		68.7			93.9	132.9		2.85	11.6	1.557	1.13	3.2
14/8					64.4			89.0	124.9		3.05	9.7	2.249	1.025	2.6
15/8*			58.8*		80.1*			91.3	124.9		2.87	35.9	0.319	1.474	10.3
16/8					73.7			95.6	143.0		2.71	6.8	2.72	1.001	6.0
17/8						74.6		96.7	138.8		2.76	6.4	2.31	1.036	3.2
18/8	20.45	29.93		48.72			63.61			162.71	3.44	11.2	2.81	1.039	6.3
19/8	23.15	35.34		52.35			67.46			175.3	3.19	12.6	2.16	1.079	1.4
20/8	20.7	29.4		45.3			60.2			154.3	3.63	11.7	2.58	1.07	2.3

*questionable calibration data

7.0 OPERATIONAL PROBLEMS AND FUTURE CONSIDERATIONS

The sonic anemometer is very sensitive to rain, frost or water droplet formation (condensation). The output signal from the sonic dishes is spurious when the dishes are wet. For those time periods when overnight rain or dew was forecast, the sensor was covered up or removed until the following morning. A series of low threshold response anemometers to measure the horizontal wind speed at a minimum of three heights should be used to provide data for an alternative way to compute of K(z) using a momentum approach. The data from the cup anemometers can be used when the sonic is out of service and as a check on the accuracy of the sonic anemometer.

The plumbing of the sample manifold system should be improved to exclude any backpressure effects from the manifold pump on the Meloy analyzer. The GAST manifold pump samples air with a total flow in the order of 20 l/min and vacuum of over 25" mercury whereas the Meloy analyzer uses only 250 cc/min in its measurements.

The differential pressure (i.e., between the analyzer pump and the ambient pressure) exerted over the critical orifice dictates the sample flow rate of the Meloy analyzer. When the larger GAST pump is parallel to the Meloy analyzer, it exerts a vacuum effect on the analyzer and upsets the Meloy's differential pressure regime and resultant flow through the critical orifice. When this happens, there is a reduced mixing air flow in the inner flame and a corresponding change in the analyzer baseline and response characteristics. For this reason, all calibration gases must be introduced through the sample manifold rather than directly into the Meloy analyzer.

In the future, pumps should be matched to minimize the backpressure effects on the SO2 analyzer. If a smaller sample manifold pump is employed, there will be reduced flow through the lines and a longer residence time. During the Crossfield study program, residence times were less than 5 s in the sample lines. As an alternative, larger diameter sample lines should be considered to increase the sample flow and reduce the residence time.

The usefullness of the glassware (as shown in figure 3) inside the sample manifold should be assessed. Their intended purpose is to mix the air samples thoroughly and remove any noise associated with SO2 fluctuations. It appears that this may be unnecessary in view of tests without the

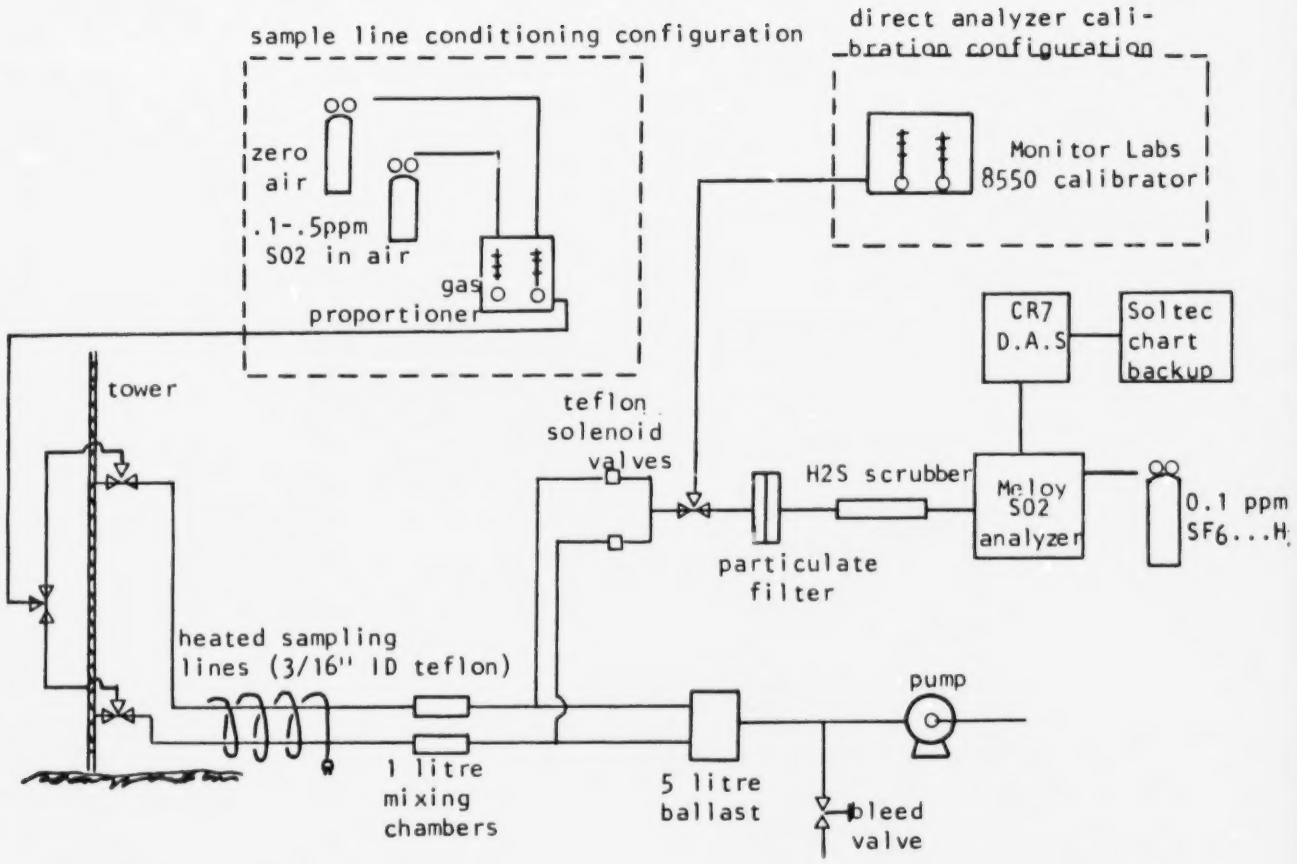

Figure 3. Concentration gradient profile and calibration system layout. D.A.S.-Data Acquisition System

glassware. The absorption by the manifold is reduced and the response time is decreased by removing the 1 litre glass mixing vessels.

The stability of the analyzer baseline is very sensitive to temperature and voltage fluctuations and as such can drift slightly hour to hour. To improve the accuracy in determining where the baseline is located, additional calibration checks could be implemented by making use of the remotely activated solenoid valves which supply SO2 free air followed by a known concentration of SO2 gas into the Meloy at scheduled periods. The single level of SO2 gas is also helpful in assessing the stability of the analyzer's response to a known concentration of gas. The external solenoid valves ould be activated by the CR7 datalogger.

8.0 RESULTS

Table 2 presents an executive summary of deposition velocities under a variety of wind, stability, temperature and relative humidity conditions. More detailed data records including results of the minisonde releases are provided in the appendix.

The deposition velocities are presented as weighted averages of the 15 minute values over the time period noted in the table. The formula used for the weighted deposition velocities is given below:

$$V_d = \frac{(\sum_i V_i/\varepsilon_i)}{\sum_i (1/\varepsilon_i)}$$

Vi is the deposition velocity for the 15 minute sampling period and Ei is the estimated error. Errors in concentrations were inferred from the least square fit between calibrator concentration and analyzer net response following Miller and Freund (1965:235). Errors in Kh and all other meteorological variables were estimated by the propagation of error method as described in Livingston (1957:22-29). Concord Scientific's error analysis was based on the sensitivity of the instrument. This error analysis is more appropriate for estimating the uncertainty in the measurement of concentration gradient under optimum conditions. For absolute concentration measurements, error analysis should be based on the assessment of the calibration results. As the mean SO2 concentration is needed for the computation of the dry SO2 deposition velocity, the latter approach was used in the report for all concentration measurements, including the determination of gradients.

Estimates of the accuracy of the deposition velocity measurements are described in terms of the error associated with each measureable parameter. The Appendix displays these calculated errors for the important quantities. The greatest amount of relative uncertainty in measurement is associated with SO2 gradients where errors over 100 percent are possible. In general, the larger the SO2 gradient, the smaller the error associated with measurements. A good example is shown in the Appendix on the 18th of August at 1530 when an apparent negative SO2 flux was detected. It is evident that the error associated with this value is much larger and the flux could in fact be positive.

Table 2. Average deposition velocities and average environmental conditions during SO2 episodes.

Date	Time (MST)	Deposition Velocity (cm/s)	Wind Direction	Wind Speed (km/h)	σ_θ (deg.)	Relative Humidity (%)	Temperature (°C)	MST[1] Stability Class
08/8/83	0815-1315	0.6	185	20	9	76	22	D
10/8/83	2100-2215	1.4	326	9	6	78	21	E
11/8/83	0800-1145	0.9	336	19	7	76	21	E
14/8/83	0715-1000	1.1	170	20	7	80	16	E
15/8/83[2]	0600-1300	1.0	189	20	9	71	17	D
16/8/83	0930-1200	0.7	345	6	29	44	25	A
16/8/83	1645-2000	0.3	359	13	9	28	25	D
16/8/83	2000-2300	0.7	197	12	6	68	16	E
17/8/81	0030-0330	0.08	348	3	27	90	7	F
17/8/83	0330-0500	0.03	197	5	19	94	5	F
17/8/83	0945-1245	0.6	216	12	21	41	27	B
18/8/83	1415-1630	1.6	338	4	46	78	15	A

[1]The modified sigma theta stability class is based upon the standard deviation of wind direction and the wind speed at a height of 10 m.

[2]questionable calibration results

The precision of deposition velocity should be estimated in terms of their repeatability as a function of concentration, as the concentration determination is the precision controlling step in the present measurements. The precision of concentration measurements can be estimated from the daily calibration data (Table 1). A relative standard deviation of four to ten percent of the mean was observed for the SO2 concentration range from 65 ug/m^3 to 569.9 ug/m^3. No apparent concentration dependence of the relative standard deviation was noted.

Deposition velocities from the field trails and those assigned by Western Research (1978) are shown in Figure 4 as a function of the stability classes. The modified sigma theta (MST) stability classification was used to determine stability classes during the field trials (Mitchell 1981). The wind speed and the standard deviation of the 10 m wind vector direction are used to determine the stability classes. The stable classes, F and G, have been combined in the field trial data. Generally there is fair agreement between assigned and measured values of Vd, however the assigned values of Vd during the unstable classes (A-C), tend to be larger than the measured ones.

Figure 5 depicts the averaged measured deposition velocities as a function of relative humidity. There appears to be a directly proportional relationship between the two variables during daylight hours (correlation coefficient = 0.73; slope = 0.014 cm/s per % relative humidity).

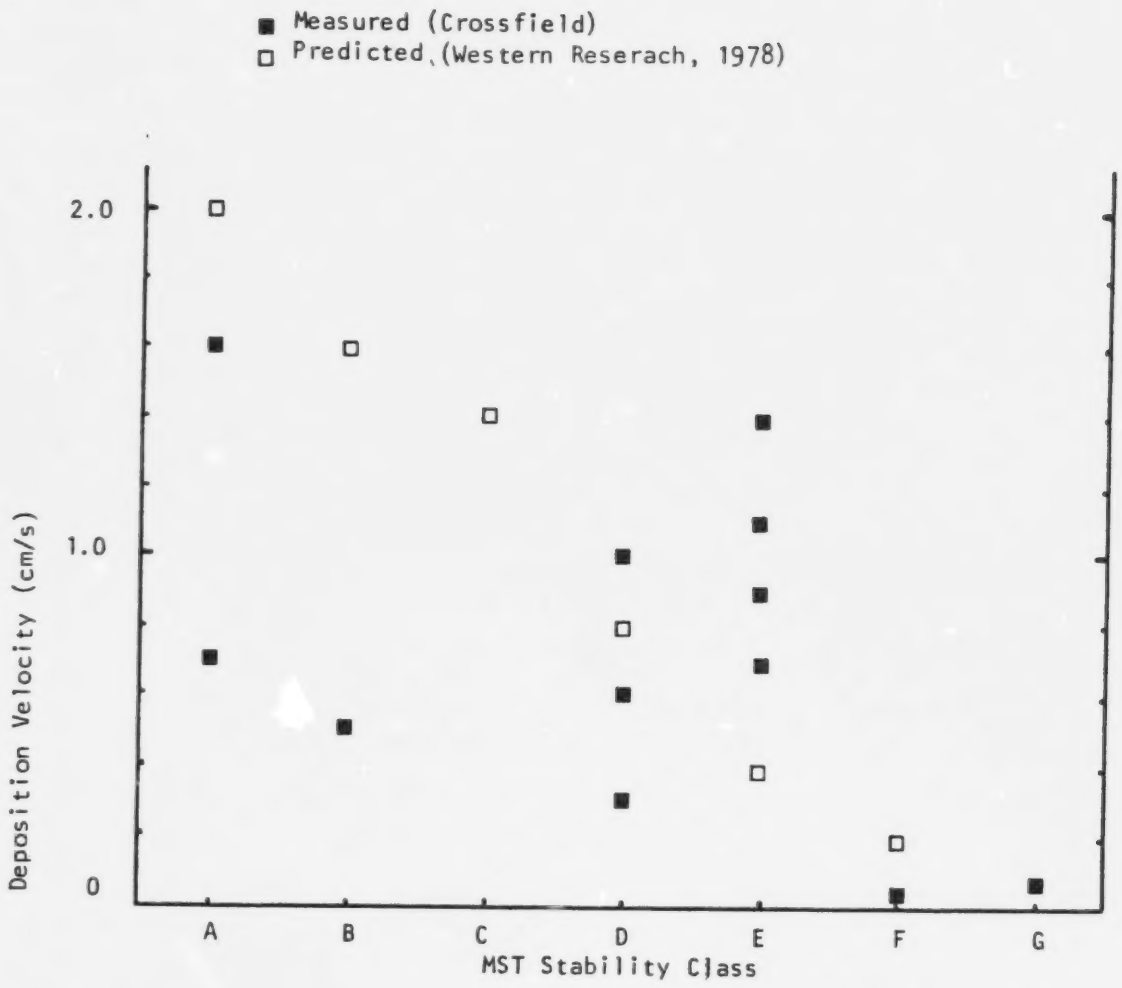

Figure 4. Average SO_2 deposition velocity as a function of modified sigma theta (MST) vertical stability class (Mitchell, 1981).

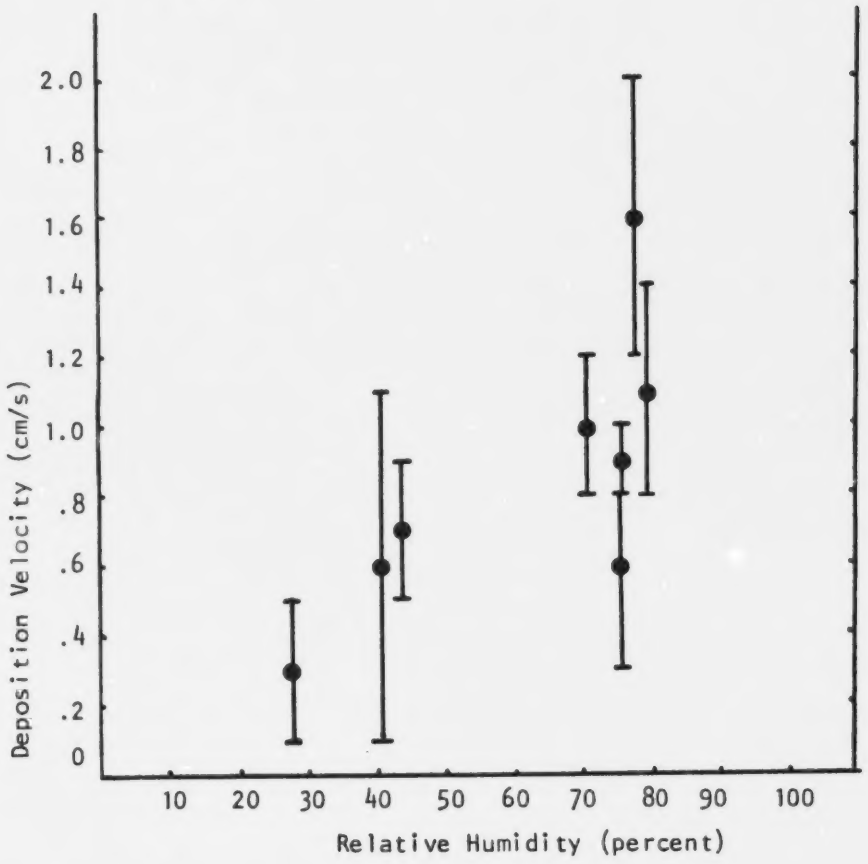

Figure 5. Average SO_2 deposition velocity as a function of relative humidity during daytime SO_2 episodes.

9.0 STOMATAL RESISTANCE

Stomatal resistance is a measure of a plant's ability to exchange water vapour and other gaseous quantities with its environment. When the resistance is high during the daylight hours, generally it is because the plant is stressed.

Stomatal resistance measurements were undertaken on August 5, 7 and 9. The spring barley crop was planted during the week of May 15-21. The crop was 90 to 100 cm in height on August 5, showing complete browning and withering on the bottom leaves and a faint speckling on the upper pairs of leaves. Because of the very dry and hot field conditions in August, ripening of the head proceeded rapidly. Samples of leaf temperature, incoming solar radiation, stomatal resistance and estimates of transpiration were made. Stomatal resistance results are difficult to correlate because of the variety of leaf characteristics encountered which will affect measurements. These include leaf orientation, maturity, exposure to sunlight as well as nutritional and water factors. Because of these factors, samplings were made only at times of the day of interest.

By August 9, there were no leaves available for making measurements that didn't display scattered brown spots due to the ripening process. As a result, no concurrent measurements of SO2 dry deposition velocity and stomatal resistance were made. Stomatal resistance values before August 9 lay within the range 2.1-6.9 cm/s. Stomatal resistance values beyond this date were essentially infinite (greater than 10 cm/s) as the crop became senescent and there were few green leaves present. The stomata are assumed to be closed at this stage of maturity, therefore SO2 removal in the crop canopy must be by removal processes other than stomatal gas exchange (Fowler and Unsworth 1979). These include absorption on the surfaces of leaves and stems and absorption of the soil surface.

Table 3. Summary of stomatal resistance measurements.

Date	Time (MST)		Number of Leaves Sampled	Leaf Temperature (°C)	Relative Humidity (%)	Quanta (moles/ m^2/s)	Stomatal Resistance (cm/s)	Transpiration Rate (g/cm^2/m)
5	1330	lower leaves (48 cm)	16	33.4	25.8	471	6.9	6.5
		upper leaves (64 cm)	12	33.4	25.9	903	3.0	9.7
7	0746	48 cm	9	18.1	59.3	168	2.8	2.9
		64 cm	9	17.9	59.3	257	2.9	2.3
	1230	48 cm	15	30.3	32.8	1044	2.1	9.9
		64 cm	9	30.4	26.7	918	2.3	9.5
	1445	48 cm	6	32.1	33.3	1163	2.5	9.3
		64 cm	2	31.3	33.6	647	2.4	8.8
9	1030	48 cm	12	30.3	41.0	835	3.6	5.7

10.0 CONCLUSIONS

It is possible to measure SO2 gradients over a crop such as barley and to estimate the deposition velocity. Using the eddy diffusivity constant derived from heat fluxes both daytime and nighttime fluxes of SO2 can be calculated.

The gradient measuring apparatus is transportable in that is does not have to be in a laboratory environment although there are moisture, temperature, power and topographical restrictions. Doping of a flame photometric SO2 analyzer with SF6 in its hydrogen source does enhance the sensitivity of the unit and enables the operator to measure lower detectable limits of SO2.

Calibration of the SO2 analyzer is important especially in the lower concentration range where ambient levels frequently occur.

Dry SO2 deposition velocities of approximately 0.1 cm/s in the evening and 1.0 cm/s during morning daylight hours were measured over ripe barley in the field experiments.

11.0 REFERENCES

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12.0 APPENDIX

SO2 DEPOSITION VELOCITY DATA SUMMARY-CROSSFIELD

Date	Time (MST)	Kh (m^2/s)	$\frac{d[SO2]}{dz}$ ($\mu g/m^4$)	$\overline{[SO2]}$ ($\mu g/m^3$)	QSO2 ($\mu g/m^2/min.$)	Vd (cm/s)	$\bar{u}_2$ (km/h)	$\bar{\theta}$ (degrees)	$\bar{T}$ (C)	RH (%)	Comments
8/8/83	0830	.26±.03	--	--			10.1	164	15	85	Flaring at Amoco plant
	0845	.30±.03	.12±.2	8.0±.5	2.2±3	.47±.7	13.8	171	15	81	in A.M.
	0900	.35±.04	.15±.3	11.0±.6	3.2±4	.50±.7	15.7	185	16	77	-new PMT in Meloy
	0915	.37±.04	.18±.3	10.8±.6	4.0±5	.61±.7	17.3	203	17	75	analyzer
	0930	.40±.04	.20±.3	11.9±.7	4.5±5	.64±.7	18.1	203	19	71	-Meloy operated with
	0945	.36±.04	.24±.3	13.6±.7	4.9±4	.61±.5	14.9	197	20	70	cover off to prevent
	1000	.34±.03	.23±.3	12.4±.7	4.5±4	.61±.6	14.4	192	20	69	overheating
	1015	.41±.04	.11±.2	7.2±.5	2.8±3	.66±.8	17.9	185	20	68	
	1030	--		--	--	--	24.6	191	20	67	
	1045	--		--	--	--	23.2	187	21	66	
	1100	--		--	--	--	23.5	189	23	64	
	1115	--		--	--	--	25.2	186	23	62	
	1130	.55±.06	.10±.2	7.1±.5	3.2±5	.75±1.1	23.4	174	25	60	
	1145	.55±.06	.08±.2	6.5±.5	2.6±5	.69±1.2	23.7	177	24	62	
	1200	--	--	--	--	--	24.3	174	25	61	
	1215	--	--	--	--	--	24.4	175	24	61	
	1230	--	--	--	--	--	24.5	168	25	62	
	1245	--	--	--	--	--	26.7	172	26	63	
	1300	.57±.06	.08±.2	5.9±.4	2.9±5	.84±1.4	26.3	176	26	60	
	1315	.58±.06	.14±.3	8.2±.6	4.9±10	.99±2	25.8	169	26	60	
10/8/83	2115	.12±.03	.05±.03	.4±.03	.4±.3	1.3 ± .9	6.9	198	22	72	Multilevel calibration
	2130	.14±.04	.29±.04	1.9±.09	2.5±3	2.1 ±2	8.7	201	22	79	testing in afternoon..
	2145	.15±.04	.72±.1	5.7±.2	6.5±2	1.9 ± .5	10.2	182	21	79	-A/C left off overnight
	2200	.12±.03	.69±.1	7.5±.3	4.7±1	1.1 ± .3	8.9	171	20	80	
	2215	.17±.04	.47±.1	4.8±.2	3.7±3	1.3 ± .9	10.0	173	20	80	

SO2 DEPOSITION VELOCITY DATA SUMMARY-CROSSFIELD

Date	Time (MST)	Kh (m^2/s)	$\frac{d(\overline{SO2})}{dz}$ ($\mu g/m^4$)	$(\overline{SO2})$ ($\mu g/m^3$)	Q_{SO2} ($\mu g/m^2/min.$)	Vd (cm/s)	$\bar{u}_2$ (km/h)	$\bar{\theta}$ (degrees)	$\bar{T}$ (C)	RH (%)	Comments
11/8/83	0815	.29±.03	0.6±.1	8.8± .2	7± 1	1.2± .2	15.6	305	18	92	
	0830	.37±.04	0.7±.1	12.5± .3	16± 2	2.2± .4	17.6	312	18	89	
	0845	.38±.04	2.0±.2	21.5± .4	47± 6	3.6± .5	19.2	310	18	88	
	0900	.38±.04	2.7±.5	65.2±1.2	62±11	1.6± .3	19.6	309	18	86	No sonic until
	0915	.37±.04	1.4±.4	115.6± .9	36±12	.5± .2	19.3	308	20	83	afternoon (1300 MST)
	0930	.40±.04	.7±.4	94.7± .8	16± 9	.3± .2	19.4	324	21	75	
	0945	.44±.04	.4±.2	38.9± .5	11± 5	.9± .4	21.3	330	22	70	
	1000	.47±.05	.3±.1	18.0± .3	8± 4	1.0± .6	22.0	335	21	70	
	1015	.44±.04	.3±.2	21.9± .4	9± 4	.8± .4	21.9	336	21	72	
	1030	.39±.04	.3±.2	27.7± .4	8± 5	.4± .2	20.9	334	21	73	
	1045	.33±.03	.1±.2	24.6± .4	1± 5	.1± .3	17.9	334	21	74	
	1100	.34±.03	-.1±.2	15.9± .4	-2± 2	-.2± .4	18.6	336	22	73	
	1115	.35±.04	.4±.1	9.9± .2	2± 2	.8± .8	16.4	339	24	67	
	1130	.40±.04	.2±.08	6.0± .2	5± 2	1.2± .5	17.6	338	23	67	
	1145	.39±.04	.1±.08	6.0± .2	2± 2	.6± .6	16.7	336	22	68	
14/8/83	0730	.25±.05	1.0±.6	25.5±1.2	15± 8	1.0± .6	17.1	334	12	91	1/10 Ac
	0745	.27±.06	.7±.6	23.6±1.2	12±10	.9± .8	17.5	341	12	89	
	0800	.30±.08	.7±.5	17.7±1.0	12±12	1.1±1.1	18.3	335	13	88	1/10 Sc to north
	0815	.34±.09	.6±.5	17.0±1.0	13±11	1.3±1.1	20.4	333	14	86	moderate-gusty
	0830	.31±.08	.4±.4	12.7± .8	7± 7	.9± .9	18.5	334	15	85	ground breeze
	0845	.37±.09	.2±.3	8.2± .6	4± 6	.9±2.0	20.5	337	16	83	flaring 0800-0815 MST
	0900	.39±.10	.2±.2	6.8± .5	5± 6	1.3±1.5	22.1	336	17	79	
	0915	.39±.10	.3±.2	7.2± .5	6± 5	1.3±1.0	21.2	333	18	76	
	0930	.40±.10	.3±.3	9.0± .7	7± 7	1.2±1.2	20.7	335	19	72	
	0945	.34±.09	.3±.3	8.2± .6	5± 5	1.0±1.0	20.6	334	20	69	
	1000	.35±.09	--	3.1± .3	--	--	22.5	340	21	64	power plant oil checkout

SO2 DEPOSITION VELOCITY DATA SUMMARY-CROSSFIELD

Date	Time (MST)	Kh (m^2/s)	$\frac{d(SO2)}{dz}$ ($\mu g/m^4$)	$\overline{(SO2)}$ ($\mu g/m^3$)	QSO2 ($\mu g/m^2/min.$)	Vd (cm/s)	$\bar{u}_2$ (km/h)	$\bar{\theta}$ (degrees)	$\bar{T}$ (C)	RH (%)	Comments
15/8/83	0615	.14±.04	.1±.1	3.0± .2	.6± .6	.3± .3	10.5	179	6	95	moderate to strong
	0630	.12±.04	.1±.1	2.8± .2	.6± .6	.3± .3	9.1	180	6	94	gusts at ground
	0645	.16±.05	.1±.1	3.0± .2	1.2± 1	.7± .7	11.7	173	6	95	scattered Sc to west
	0700	.17±.05	.2±.1	4.4± .3	2.4± 1	.9± .5	11.1	166	6	96	(less than 1/10)
	0715	.23±.07	.2±.2	5.7± .4	3.0± 2	.9± .6	14.4	168	7	96	
	0730	.18±.05	.1±.2	5.3± .4	1.8± 2	.5± .4	12.7	169	8	97	questionable calibration
	0745	.19±.06	.1±.1	4.3± .3	1.2± 2	.5± .7	13.8	166	9	97	results
	0800	.25±.08	.1±.1	3.1± .2	1.8± 2	.9±1	17.2	162	11	96	
	0815	.35±.1	.2±.1	2.8± .2	3.6± 4	2.2±2	21.8	159	12	95	
	0830	.36±.04	.4±.2	6.8± .4	8.4± 4	2.0±1	23.0	164	13	93	
	0845	.65±.07	.6±.4	15.9± .8	22.8±14	2.4±1	23.7	169	14	88	
	0900	.98±.1	.7±.5	24.5±1	38.4±26	2.6±2	28.6	172	14	80	
	0915	.93±.09	.5±.6	25.9±1	27.0±27	1.7±2	28.6	172	15	74	
	0930	.65±.07	.2±.4	19.5± .9	7.8±11	.7±1	28.1	170	16	69	
	0945	.86±.09	.3±.4	19.3± .9	13.8±16	1.2±1	30.3	165	16	65	
	1000	.92±.09	.6±.6	32.6±1	31.8±21	1.6±1	26.2	177	17	64	
	1015	.93±.09	.5±.6	40.2±1	26.4±26	1.1±1	27.5	174	18	63	
	1030	.87±.09	.2±.6	36.2±1	11.4±24	.5±1	25.5	173	19	62	
	1045	.69±.07	.1±.6	33.6±1	6.0±15	.3± .7	23.7	173	20	59	
	1100	.74±.07	.1±.6	30.6±1	3.0±16	.2±1	25.1	174	21	57	
	1115	.77±.08	0	24.9±1	0	0	24.1	169	22	55	
	1130	.84±.08	.0±.5	22.5±1	1.2± 6	.1± .5	21.8	170	22	52	
	1145	.77±.08	0 ±.5	22.3±1	--	--	20.5	166	24	49	
	1200	.71±.07	0	19.8± .9	--	--	17.2	173	25	47	
	1215	.69±.07	0 ±.4	15.3± .8	.6± 2	.1± .4	20.6	164	26	44	
	1230	.62±.06	.1±.3	12.1± .7	1.8± 5	.3±1	17.6	178	26	43	
	1245	.65±.07	.1±.3	12.5± .7	4.8± 8	.7±1	18.7	171	27	41	
	1300	.61±.06	.3±.4	15.0± .8	10.2±10	1.1±1	19.6	172	27	41	
	1315	.76±.06	--	--	--	--	16.0	176	29	39	

SO2 DEPOSITION VELOCITY DATA SUMMARY-CROSSFIELD

Date	Time (MST)	Kh (m^2/s)	$\frac{d\overline{(SO2)}}{dz}$ ($\mu g/m^4$)	$\overline{(SO2)}$ ($\mu g/m3$)	QSO2 ($\mu g/m^2/min.$)	Vd (cm/s)	$\overline{u}_2$ (km/h)	$\overline{\theta}$ (degrees)	$\overline{T}$ (C)	RH (%)	Comments
16/8/83	0945	.4 ± .1	.4 ± .04	4.2± .2	10±2	4 ±1	2.4	195	18	59	Sonic out of service
	1000	.3 ± .1	.4 ± .1	11.0± .3	8±2	1.2± .5	2.5	189	20	53	overnight due to
	1015	.5 ± .1	.2 ± .2	16.2± .4	6±6	.6± .6	4.4	176	21	51	threat of showers
	1030	.6 ± .1	.2 ± .2	18.9± .5	5±9	.5± .5	5.0	194	23	48	
	1045	.5 ± .1	.2 ± .2	20.7± .5	6±6	.5± .5	6.6	181	24	46	
	1100	.4 ± .1	.2 ± .2	22.0± .5	6±5	.5± .4	8.9	186	26	43	
	1115	.4 ± .1	.1 ± .2	20.3± .5	4±7	.3± .5	8.9	186	27	40	
	1130	.4 ± .1	.1 ± .2	13.7± .4	2±4	.3± .6	6.4	197	28	37	
	1145	.6 ± .1	.2 ± .1	7.9± .3	5±3	1.1± .7	7.1	182	29	35	
	1200	.4 ± .1	.2 ± .1	4.6± .1	3±1	1.1± .4	5.9	201	30	32	power plant problems from 1330-1700 MST

SO2 DEPOSITION VELOCITY DATA SUMMARY-CROSSFIELD

Date	Time (MST)	Kh (m^2/s)	$\frac{d(\overline{SO2})}{dz}$ ($\mu g/m^4$)	$(\overline{SO2})$ ($\mu g/m3$)	Q_{SO2} ($\mu g/m^2/min.$)	Vd (cm/s)	$\overline{u}_2$ (km/h)	$\overline{\theta}$ (degrees)	$\overline{T}$ (C)	RH (%)	Comments
16/8/83	1700	.65±.07	3.6±.5	74 ±1	106±18	2.4 ± .8	11.6	330	28	19	
	1715	1.33±.2	4.2±.6	86 ±1	336±80	6.5 ±1.6	21.7	322	30	18	
	1730	.30±.03	1.8±.3	44 ± .7	31± .6	1.2 ± .3	22.8	309	28	19	
	1745	-.1±.2	-.1±.2	17 ± .4	-2± 4	-.2 ± .4	16.8	330	28	20	
	1800	.40±.04	.2±.2	16 ± .4	1± 1	.1 ± .1	14.1	2	27	21	
	1815	.29±.03	.1±.2	17 ± .4	1± 2	.1 ± .2	14.2	350	26	23	
	1830	.21±.02	.1±.2	17 ± .4	1± 2	0 ± .2	13.7	349	26	23	
	1845	.00±.01	.2±.2	16 ± .4	0	0	12.1	350	25	25	
	1900	.89±.20	.2±.2	17 ± .4	11±15	1.1 ±1.4	10.5	356	24	28	
	1915	.14±.01	.3±.2	13 ± .4	2± 1	.3 ± .2	8.5	358	23	34	
	1930	.07±.01	.3±.2	13 ± .4	1± 1	.2 ± .1	8.6	355	22	42	
	1945	.08±.01	.4±.2	11 ± .3	2± 1	.3 ± .1	9.5	353	21	46	
	2000	.06±.005	.5±.1	9.3± .3	2± .5	.3 ± .1	9.4	355	20	49	
	2015	.04±.005	.4±.1	7.1± .2	1± .2	.3 ± .1	9.3	1	19	52	
	2030	.03±.005	.5±.1	5.7± .2	1± .2	.3 ± .1	8.4	4	19	56	
	2045	.03±.005	.5±.1	5.4± .2	1± .2	.3 ± .1	8.5	5	18	59	
	2100	.03±.005	.5±.1	5.7± .2	1± .2	.3 ± .1	8.6	1	17	63	
	2115	.06±.005	.5±.1	8.1± .3	2± .4	.4 ± .1	11.4	353	16	63	
	2130	.16±.02	.5±.2	12 ± .3	5± 2	.7 ± .2	15.6	349	16	66	
	2145	.16±.02	.6±.2	14 ± .4	6± 2	.7 ± .2	13.4	343	16	70	
	2200	.22±.02	.7±.2	13 ± .4	9± 2	1.2 ± .3	14.0	352	15	72	
	2215	.14±.01	.8±.1	10 ± .3	7± 1	1.2 ± .2	11.2	359	15	73	
	2230	.12±.01	.9±.1	8.1± .3	7± 1	1.4 ± .2	12.2	2	14	79	
	2245	.19±.02	.7±.1	6.4± .2	8± 1	2.1 ± .3	14.2	12	14	81	
	2300	.18±.02	.4±.1	3.6± .1	5± 1	1.7 ± .3	14.0	11	13	81	

SO2 DEPOSITION VELOCITY DATA SUMMARY-CROSSFIELD

Date	Time (MST)	Kh (m^2/s)	$\frac{d\overline{(SO2)}}{dz}$ ($\mu g/m^4$)	$\overline{(SO2)}$ ($\mu g/m3$)	QSO2 ($\mu g/m^2/min.$)	Vd (cm/s)	$\overline{u}_2$ (km/h)	$\overline{\theta}$ (degrees)	$\overline{T}$ (C)	RH (%)	Comments
17/8/83	0045	.017±.002	.3±.03	1.5±0.05	.3±.08	.29±.08	3.5	312	9	87	1/10 AC
	0100	.006±.001	.7±.05	3.4±0.1	.2±.02	.11±.01	2.4	7	8	88	weak inversion
	0115	.005±.001	.7±.06	4.0±0.1	.2±.02	.09±.01	6.4	345	8	88	visibility 15+km
	0130	.002±.001	.7±.06	4.3±0.1	.1±.03	.03±.005	1.6	342	8	88	
	0145	.007±.001	.7±.07	5.6±0.2	.3±.03	.08±.01	3.7	339	7	90	
	0200	.002±.001	.7±.08	6.3±0.2	.1±.02	.02±.004	1.4	357	7	91	
	0215	.011±.001	.5±.08	6.8±0.2	.4±.06	.11±.02	Calm		7	91	
	0230	--	.3±.08	7.0±0.2	--	--	1.5	324	6	90	
	0245	.007±.001	.3±.08	6.4±0.2	.2±.04	.06±.01	5.5	350	6	91	
	0300	.004±.001	.3±.07	5.4±0.2	.1±.04	.02±.005	4.3	353	6	91	
	0315	.007±.001	.3±.06	4.9±0.1	.1±.03	.04±.01	0.7	15	5	91	moderate inversion
	0330	.00	.4±.06	4.7±0.1	0	.0	0.3	5	5	90	
	0345	.00	.5±.07	5.1±0.1	0	.0	1.5	201	5	91	
	0400	.013±.001	.3±.07	5.8±0.2	.2±.2	.06±.04	7.1	196	5	93	
	0415	.00	.1±.07	5.7±0.1	0	.0	4.2	193	5	95	
	0430	.009±.001	.1±.07	5.1±0.1	0	.01±.01	4.7	200	5	94	
	0445	.017±.002	.1±.06	4.4±0.1	.1±.06	.03±.02	4.4	195	5	94	
	0500	.05 ±.006	.1±.05	3.7±0.1	.2±.1	.10±.05	8.6	194	5	94	generator check at 0700 MST
	1000	.33 ±.04	.8±.2	39.7±0.5	16 ± 4	.7 ±.2	18.5	190	20	65	clear overhead
	1015	.30 ±.03	.5±.2	39.1±0.5	9 ± 4	.4 ±.2	17.0	194	21	61	1/10 Ac to the west
	1030	.30 ±.03	.4±.2	34.2±0.5	7 ± 4	.3 ±.2	15.0	192	23	58	1/10 Cu
	1045	.26 ±.03	.3±.2	26.1±0.4	4 ± 4	.3 ±.3	14.3	176	24	53	cap smell H2S
	1100	.24 ±.03	.3±.2	18.6±0.3	4 ± 3	.3 ±.2	12.9	186	25	48	
	1115	.28 ±.03	.3±.1	12.7±0.2	5 ± 2	.7 ±.3	11.9	199	26	43	visibility 40 km
	1130	.28 ±.03	.2±.07	7.2±0.2	4 ± 1	1.0 ±.3	8.9	206	28	38	no precipitation in
	1145	.26 ±.03	.1±.04	2.7±0.09	1 ±13	.9 ±8	13.2	223	29	32	last 24 hours
	1200	.32 ±.03	.0±.03	.8±0.07	.3± 2	.7 ±2	12.0	241	30	26	
	1215	.32 ±.03	0±.01	.4±0.03	.2± .8	1.0 ±4	13.3	265	31	23	
	1230	.33 ±.04	.0±.01	.2±0.02	.1± .3	.5 ±2	8.3	252	30	22	
	1245	.47 ±.05	.0±.01	.2±0.02	.1± .5	.5 ±3	10.9	267	32	19	

SO2 DEPOSITION VELOCITY DATA SUMMARY-CROSSFIELD

Date	Time (MST)	Kh (m^2/s)	$\frac{d(\overline{SO2})}{dz}$ ($\mu g/m^4$)	$\overline{(SO2)}$ ($\mu g/m3$)	Q_{SO2} ($\mu g/m^2/min.$)	Vd (cm/s)	$\overline{u}_2$ (km/h)	$\overline{\theta}$ (degrees)	$\overline{T}$ (C)	RH (%)	Comments
18/8/83	1430	.3±.1	7 ±1	78±2	101±29	2.2±.6	4.2	244	13	92	Sonic out of service
	1445	.3±.1	6 ±1	134±3	84±29	1.1±.4	2.9	198	15	87	
	1500	.2±.1	3 ±1	110±3	31±20	.5±.3	3.3	358	15	81	
	1515	.3±.1	.7± .7	61±2	14±17	.4±.5	4.3	298	16	83	
	1530	.5±.2	-.1± .7	34±1	-2±15	=.1±.8	4.6	15	16	77	
	1545	.6±.2	.1± .2	14± .5	2± 4	.3±.6	6.0	13	16	77	
	1600	.7±.2	.4± .1	6± .3	17± 7	4.7±2	4.7	28	16	73	
	1615	.7±.3	.3± .1	5± .3	15± 7	5.3±3	2.9	33	16	68	
	1630	.3±.1	.1± .1	1± .1	1± 1	2.3±2	5.7	59	16	64	

MINISONDE DATA SHEET

PROJECT NO. Alta. Envt. Crossfield NAME: MS1

DATE: 26 July 1983 TIME OF RELEASE: 1453 MST

CHART SPEED: _____ TEMP. SPAN: _____ OBSERVER: _____

CALIBRATION TEMP: _____ RELEASE TEMP: 19.9°C OBSERVER: _____

BASELINE DIRECTION: True North PLUME OBS. 1 2 3 4 5 6 7 8 9

ascent rates approximately 180 m/min unless stated otherwise

COMMENTS: one theodolite only 5/10 SC gusty west winds

MINISONDE		THEODOLITE NO. 1		WIND	
TIME	TEMP. °C	AZIMUTH	ELEVATION	SPEED (M/S)	DIRECTION
0.0	19.9				
0.5	18.6	70.4	12.0	14.2	251
1.0	17.5	72.2	11.9	13.4	253
1.5	16.8	71.6	12.4	13.8	250
2.0	16.4	71.0	12.1	15.1	250
2.5	15.8	70.8	11.9	15.5	251
3.0	14.9	71.1	11.7	15.6	252
3.5	14.3	71.0	11.6	14.5	250
4.0	13.4	70.9	11.7	12.4	249
4.5	12.7	70.5	12.0	9.8	244
5.0	11.7	69.9	12.5	5.9	237
5.5	10.3	69.4	13.4	5.1	245
6.0	9.1	69.6	13.9	6.7	255
6.5	8.2	69.9	14.4	6.8	254
7.0	6.8	M		6.9	252
7.5	5.9	70.1	15.2	7.7	259
8.0	5.0	70.8	15.4		
8.5	4.3	M			
9.0	3.7				
9.5	2.7				
10.0	1.7	0.0	0.0		
10.5	0.9				
11.0	0.2				

MINISONDE		THEODOLITE NO. 1		THEODOLITE NO. 2	
TEMP	TEMP. °C	AZIMUTH	ELEVATION	AZIMUTH	ELEVATION
12.5					
13.0					
13.5					
14.0					
14.5					
15.0					
15.5					
16.0					
16.5					
17.0					
17.5					
18.0					
18.5					
19.0					
19.5					
20.0					
20.5					
21.0					
21.5					
22.0					
22.5					
23.0					
23.5					
24.0					
24.5					
25.0					
25.5					
26.0					

MINISONDE DATA SHEET

PROJECT NO. Alta. Envt. Crossfield NAME: MS2

DATE: 27 July 1983 TIME OF RELEASE: 1345 MST

CHART SPEED: _____ TEMP. SPAN: _____ OBSERVER: _____

CALIBRATION TEMP: _____ RELEASE TEMP: 19.8°C OBSERVER: _____

BASELINE DIRECTION: _____ PLUME OBS. 1 2 3 4 5 6 7 8 9

COMMENTS: 2/10 AC 6/10 Cl scattered SC ground breezes from NE at release-variable

MINISONDE		THEODOLITE NO. 1		WIND	
TIME	TEMP. °C	AZIMUTH	ELEVATION	SPEED (M/S)	DIRECTION
0.0	19.8				
0.5	19.8	199.6	46.4	3.1	26
1.0	18.3	197.3	44.6	2.9	26
1.5	17.4	207.3	46.6	3.0	79
2.0	16.5	229.1	50.8	3.6	110
2.5	15.3	244.4	51.2	3.5	114
3.0	14.3	254.6	51.3	2.5	116
3.5	13.3	257.3	53.1	1.9	108
4.0	12.0	261.8	53.6	2.6	123
4.5	10.7	268.4	53.9		
5.0	9.5	0.0	0.0		
5.5	8.6				
6.0	7.9				
6.5	7.0				
7.0	6.6				
7.5	6.3				
8.0	6.0				
8.5	5.7				
9.0	5.0				
9.5	4.9				
10.0	4.5				
10.5	4.4				
11.0	3.6				
11.5					

MINISONDE		THEODOLITE NO. 1		THEODOLITE NO. 2	
TEMP	TEMP. °C	AZIMUTH	ELEVATION	AZIMUTH	ELEVATION
12.5					
13.0					
13.5					
14.0					
14.5					
15.0					
15.5					
16.0					
16.5					
17.0					
17.5					
18.0					
18.5					
19.0					
19.5					
20.0					
20.5					
21.0					
21.5					
22.0					
22.5					
23.0					
23.5					
24.0					
24.5					
25.0					
25.5					
26.0					

MINISONDE DATA SHEET

PROJECT NO. Alta. Envt. Crossfield NAME: MS3

DATE: 27 July 83 TIME OF RELEASE: 1628 MST

CHART SPEED: _____ TEMP. SPAN: _____ OBSERVER: RDD

CALIBRATION TEMP: _____ RELEASE TEMP: 24.1°C OBSERVER: _____

BASELINE DIRECTION: True North as calculated from compass PLUME OBS. 1 2 3 4 5 6 7 8 9

COMMENTS: 7/10 Cl 1/10 SC to SW and NW; ground breeze was ESE at time of release

MINISONDE		THEODOLITE NO. 1		WIND	
TIME	TEMP. °C	AZIMUTH	ELEVATION	SPEED (M/S)	DIRECTION
0.0	24.1				
0.5	22.0	317.4	31.3	3.0	141
1.0	21.0	319.4	40.2	1.8	148
1.5	19.4	321.6	39.7	1.4	161
2.0	18.9	324.4	37.4	1.2	204
2.5	18.1	329.3	37.5		
3.0	17.3	M			
3.5	16.3				
4.0	15.1	0.0	0.0		
4.5	14.2				
5.0	13.4				
5.5	12.3				
6.0	11.4				
6.5	10.2				
7.0	9.2				
7.5	8.4				
8.0	7.5				
8.5	6.5				
9.0	5.6				
9.5	4.9				
10.0	4.1				
10.5	3.3				
11.0	2.5				
11.5					

MINISONDE		THEODOLITE NO. 1		THFODOLITE NO. 2	
TEMP	TEMP. °C	AZIMUTH	ELEVATION	AZIMUTH	ELEVATION
12.5					
13.0					
13.5					
14.0					
14.5					
15.0					
15.5					
16.0					
16.5					
17.0					
17.5					
18.0					
18.5					
19.0					
19.5					
20.0					
20.5					
21.0					
21.5					
22.0					
22.5					
23.0					
23.5					
24.0					
24.5					
25.0					
25.5					
26.0					

MINISONDE DATA SHEET

PROJECT NO. Alta. Envt. Crossfield NAME: MS4

DATE: 3 Aug. 83 TIME OF RELEASE: 1202 MST

CHART SPEED: _____ TEMP. SPAN: _____ OBSERVER: _____

CALIBRATION TEMP: _____ RELEASE TEMP: 27.5°C OBSERVER: _____

BASELINE DIRECTION: _____ PLUME OBS. 1 2 3 4 5 6 7 8 9

COMMENTS: ground breeze light from ENE or ESE
1/10 scattered SC to W and SW; SC bank forming to E-hazy

MINISONDE		THEODOLITE NO. 1		WIND	
TIME	TEMP. °C	AZIMUTH	ELEVATION	SPEED (M/S)	DIRECTION
0.0	27.5				
0.5	25.3	317.9	28.2	6.6	137
1.0	24.7	318.5	24.5	6.2	137
1.5	23.9	316.3	26.5	5.4	129
2.0	23.0	314.0	26.7	5.1	119
2.5	22.3	309.8	28.2	3.9	97
3.0	21.2	305.2	30.6	3.1	87
3.5	20.9	302.6	32.6	2.4	90
4.0	18.7	300.6	34.8	2.8	101
4.5	17.4	299.4	35.3	3.5	116
5.0	16.6	299.9	35.8	3.5	134
5.5	16.4	301.8	36.3	3.8	152
6.0	16.0	304.8	36.8	4.3	158
6.5	15.8	307.5	36.8	4.8	163
7.0	15.2	310.9	36.9	5.4	167
7.5	14.4	314.1	36.5	6.1	168
8.0	13.7	M		6.5	174
8.5	13.1	320.7	35.6	7.8	181
9.0	12.5	325.6	34.7	9.6	188
9.5	12.0	330.2	33.7	10.8	190
10.0	11.8	334.8	32.4	11.8	193
10.5	11.7	339.0	31.2		
11.0	11.3	343.3	29.8		
11.5					

MINISONDE		THEODOLITE NO. 1		THFODOLITE NO. 2	
TEMP	TEMP. °C	AZIMUTH	ELEVATION	AZIMUTH	ELEVATION
12.5					
13.0					
13.5					
14.0					
14.5					
15.0					
15.5					
16.0					
16.5					
17.0					
17.5					
18.0					
18.5					
19.0					
19.5					
20.0					
20.5					
21.0					
21.5					
22.0					
22.5					
23.0					
23.5					
24.0					
24.5					
25.0					
25.5					
26.0					

MINISONDE DATA SHEET

PROJECT NO. Alta. Envt. Crossfield NAME: MS5

DATE: 7 Aug. 83 TIME OF RELEASE 0718 MST

CHART SPEED: _____ TEMP. SPAN: _____ OBSERVER: RDD

CALIBRATION TEMP: _____ RELEASE TEMP: 15.4°C OBSERVER: _____

BASELINE DIRECTION: T.N. PLUME OBS. 1 2 3 4 5 6 7 8 9

COMMENTS: moderate to heavy dew overnight; ground RH 71.4%; thick, low overcast; 10/10 SC; ground breeze from N-very light-not variable in speed or direction

MINISONDE		THEODOLITE NO. 1		WIND	
TIME	TEMP. °C	AZIMUTH	ELEVATION	SPEED (M/S)	DIRECTION
0.0	15.4				
0.5	15.4	155.9	33.8	5.6	345
1.0	15.4	173.0	28.4	7.7	9
1.5	15.3	177.3	24.9	8.7	12
2.0	15.5	186.2	23.3	10.7	27
2.5	15.3	192.9	20.8	12.3	34
3.0	15.0	198.9	19.5	11.7	44
3.5	14.9	204.1	19.1	11.0	55
4.0	14.7	209.5	19.0	11.2	63
4.5	14.5	214.2	18.8	11.4	71
5.0	14.5	219.3	18.8	11.6	78
5.5	14.3	223.6	18.7	12.1	80
6.0	14.1	227.7	18.5	12.5	83
6.5	13.1	231.2	18.3	13.0	84
7.0	13.6	234.6	18.0	13.5	86
7.5	13.4	237.4	17.7	14.7	82
8.0	13.2	239.6	17.1	19.4	78
8.5	13.0	241.8	16.0		
9.0	12.9	M			
9.5	13.1				
10.0	13.1				
10.5	13.2				
11.0	13.5				
11.5	13.7				

MINISONDE		THEODOLITE NO. 1		THFODOLITE NO. 2	
TEMP	TEMP. °C	AZIMUTH	ELEVATION	AZIMUTH	ELEVATION
12.5					
13.0					
13.5					
14.0					
14.5					
15.0					
15.5					
16.0					
16.5					
17.0					
17.5					
18.0					
18.5					
19.0					
19.5					
20.0					
20.5					
21.0					
21.5					
22.0					
22.5					
23.0					
23.5					
24.0					
24.5					
25.0					
25.5					
26.0					

MINISONDE DATA SHEET

PROJECT NO. Alta. Envt. Crossfield NAME: MS6

DATE: 9 Aug. 83 TIME OF RELEASE: 1006 MST

CHART SPEED: _____ TEMP. SPAN: _____ OBSERVER: RDD

CALIBRATION TEMP: 27.6 RELEASE TEMP: 26.5 OBSERVER: _____

BASELINE DIRECTION: T.N. PLUME OBS. 1 2 3 4 5 6 7 8 9

COMMENTS: 1/10 Cl to E and S; scattered SC to W; calm at ground; virtually calm at tower t

MINISONDE		THEODOLITE NO. 1		WIND	
TIME	TEMP. °C	AZIMUTH	ELEVATION	SPEED (M/S)	DIRECTION
0.0	26.5			—	—
0.5	24.8	217.2	35.9	4.1	35
1.0	24.0	214.3	36.0	3.5	30
1.5	23.3	213.4	39.1	3.7	27
2.0	22.6	210.0	37.7	4.0	21
2.5	22.0	208.9	38.4	3.2	22
3.0	21.6	207.7	39.5	2.8	26
3.5	21.2	208.5	40.5	2.6	42
4.0	21.1	210.5	41.7	2.5	49
4.5	20.4	211.8	42.7	2.8	46
5.0	20.3	213.3	42.8	2.8	37
5.5	20.2	212.5	43.5	2.5	359
6.0	20.0	208.9	44.6	3.2	331
6.5	19.9	204.1	45.6	4.4	332
7.0	19.5	198.5	45.0	4.7	319
7.5	19.1	193.1	46.3	4.9	308
8.0	18.7	186.7	46.2	5.8	311
8.5	18.4	181.1	45.8	6.3	314
9.0	17.6	176.0	44.7	6.7	316
9.5	17.1	172.2	43.6	7.0	312
10.0	16.5	167.3	42.6	7.5	302
10.5	15.9	162.8	41.8		
11.0	15.2	158.5	40.5		
11.5		end of run			

MINISONDE		THEODOLITE NO. 1		THFODOLITE NO. 2	
TEMP	TEMP. °C	AZIMUTH	ELEVATION	AZIMUTH	ELEVATION
12.5					
13.0					
13.5					
14.0					
14.5					
15.0					
15.5					
16.0					
16.5					
17.0					
17.5					
18.0					
18.5					
19.0					
19.5					
20.0					
20.5					
21.0					
21.5					
22.0					
22.5					
23.0					
23.5					
24.0					
24.5					
25.0					
25.5					
26.0					

MINISONDE DATA SHEET

PROJECT NO. Alta. Envt. Crossfield NAME: MS7

DATE: 12 Aug. 83 TIME OF RELEASE: 1020 MST

CHART SPEED: _____ TEMP. SPAN: _____ OBSERVER: _____

CALIBRATION TEMP: _____ RELEASE TEMP: 19.5oC OBSERVER: _____

BASELINE DIRECTION: _____ PLUME OBS. 1 2 3 4 5 6 7 8 9

COMMENTS: scattered SC to W, S, SE; moderate strong NNW ground breeze; clear otherwise

MINISONDE		THEODOLITE NO. 1		WIND	
TIME	TEMP. °C	AZIMUTH	ELEVATION	SPEED (M/S)	DIRECTION
0.0	20.9				
0.5	16.4	153.0	25.4	5.6	332
1.0	14.5	153.9	28.2	6.0	333
1.5	14.2	152.1	26.1	6.9	327
2.0	13.5	149.8	25.7	6.2	325
2.5	13.0	149.8	26.0	6.7	339
3.0	12.3	153.7	25.3	9.0	347
3.5	12.0	156.1	23.5	11.1	345
4.0	11.8	157.8	21.8	11.3	345
4.5	11.5	158.9	20.9	11.5	343
5.0	11.3	159.2	19.9	11.8	339
5.5	10.7	158.8	19.3	10.9	335
6.0	10.4	158.3	19.0	9.0	328
6.5	9.9	157.1	19.2	6.9	308
7.0	8.8	154.9	19.8		
7.5	7.9	M			
8.0	6.7				
8.5	5.8				
9.0	4.7				
9.5	3.8				
10.0	3.3				
10.5					
11.0					
11.5					

MINISONDE		THEODOLITE NO. 1		THEODOLITE NO. 2	
TEMP	TEMP. °C	AZIMUTH	ELEVATION	AZIMUTH	ELEVATION
12.5					
13.0					
13.5					
14.0					
14.5					
15.0					
15.5					
16.0					
16.5					
17.0					
17.5					
18.0					
18.5					
19.0					
19.5					
20.0					
20.5					
21.0					
21.5					
22.0					
22.5					
23.0					
23.5					
24.0					
24.5					
25.0					
25.5					
26.0					

MINISONDE DATA SHEET

PROJECT NO. Alta. Envt. Crossfield NAME: MS8

DATE: 13 Aug. 83 TIME OF RELEASE: 0726 MST

CHART SPEED: _____ TEMP. SPAN: _____ OBSERVER: _____

CALIBRATION TEMP: _____ RELEASE TEMP: 14.4°C OBSERVER: _____

BASELINE DIRECTION: _____ PLUME OBS. 1 2 3 4 5 6 7 8 9

COMMENTS: clear everywhere; ~~no breeze at all~~

MINISONDE		THEODOLITE NO. 1		WIND	
TIME	TEMP. °C	AZIMUTH	ELEVATION	SPEED (M/S)	DIRECTION
0.0	14.4				
0.5	16.4	63.7	68.8	2.6	247
1.0	16.8	76.1	48.8	5.0	266
1.5	17.4	82.7	39.1	5.9	271
2.0	17.2	84.9	35.4	5.4	268
2.5	16.7	84.7	34.4	4.7	260
3.0	16.1	82.7	34.5	4.5	248
3.5	15.6	79.7	34.5	4.4	238
4.0	15.0	76.6	34.9	3.3	232
4.5	14.6	75.1	36.4	1.9	240
5.0	14.1	75.0	38.2	1.4	263
5.5	13.8	75.7	40.0	1.2	276
6.0	13.2	76.2	41.7	1.2	258
6.5	12.8	75.8	43.1	1.7	207
7.0	12.4	72.8	44.6	2.7	189
7.5	12.0	69.2	45.6	3.3	187
8.0	11.4	65.2	46.4	4.3	188
8.5	11.0	60.1	46.3	5.6	190
9.0	10.3	55.1	45.6	6.2	195
9.5	9.7	51.4	44.4	7.0	201
10.0	9.1	48.2	42.7	7.7	204
10.5	8.6	45.9	41.1		
11.0	8.0	43.8	39.6		
11.5					

MINISONDE		THEODOLITE NO. 1		THEODOLITE NO. 2	
TEMP	TEMP. °C	AZIMUTH	ELEVATION	AZIMUTH	ELEVATION
12.5					
13.0					
13.5					
14.0					
14.5					
15.0					
15.5					
16.0					
16.5					
17.0					
17.5					
18.0					
18.5					
19.0					
19.5					
20.0					
20.5					
21.0					
21.5					
22.0					
22.5					
23.0					
23.5					
24.0					
24.5					
25.0					
25.5					
26.0					

MINISONDE DATA SHEET

PROJECT NO. Alta. Envt. Crossfield NAME: MS9

DATE: 13 Aug. 83 TIME OF RELEASE: 1144 MST

CHART SPEED: _____ TEMP. SPAN: _____ OBSERVER: RDD

CALIBRATION TEMP: _____ RELEASE TEMP: 24.6°C OBSERVER: _____

BASELINE DIRECTION: _____ PLUME OBS. 1 2 3 4 5 6 7 8 9

COMMENTS: 0/10 in all directions; moderate to strong southerly gusts; SO2 readings showing up at this time

MINISONDE		THEODOLITE NO. 1		WIND	
TIME	TEMP. °C	AZIMUTH	ELEVATION	SPEED (M/S)	DIRECTION
0.0	24.6				
0.5	22.8	9.6	11.4	15.7	191
1.0	22.5	12.6	10.8	14.1	197
1.5	22.2	13.6	11.8	12.3	194
2.0	21.9	13.0	12.1	13.2	188
2.5	21.2	11.2	12.2	7.6	176
3.0	21.2	9.7	14.3		
3.5	20.3	lost			
4.0	19.7				
4.5	19.1				
5.0	18.3				
5.5	17.7				
6.0	17.0				
6.5	16.1				
7.0	15.2				
7.5	14.3				
8.0	13.8				
8.5	13.5				
9.0	13.3				
9.5	13.1				
10.0	12.8				
10.5					
11.0					
11.5					

MINISONDE		THEODOLITE NO. 1		THFODOLITE NO. 2	
TEMP	TEMP. °C	AZIMUTH	ELEVATION	AZIMUTH	ELEVATION
12.5					
13.0					
13.5					
14.0					
14.5					
15.0					
15.5					
16.0					
16.5					
17.0					
17.5					
18.0					
18.5					
19.0					
19.5					
20.0					
20.5					
21.0					
21.5					
22.0					
22.5					
23.0					
23.5					
24.0					
24.5					
25.0					
25.5					
26.0					

MINISONDE DATA SHEET

PROJECT NO. Alta. Envt. Crossfield NAME: MS10

DATE: 14 Aug. 83 TIME OF RELEASE: 0648 MST

CHART SPEED: _____ TEMP. SPAN: _____ OBSERVER: RDD

CALIBRATION TEMP: 13.7 RELEASE TEMP: 13.4 OBSERVER: _____

BASELINE DIRECTION: _____ PLUME OBS. 1 2 3 4 5 6 7 8 9

COMMENTS: 1/10 AC 1/10 SC; bank of SC to NW; moderate to strong N-NNW ground breeze

MINISONDE		THEODOLITE NO. 1		WIND	
TIME	TEMP. °C	AZIMUTH	ELEVATION	SPEED (M/S)	DIRECTION
0.0	13.4				
0.5	13.8	145.0	behind furnace		
1.0	13.5	145.0	stack	16.6	326
1.5	14.6	150.0	12.7	25.4	335
2.0	15.8	151.2	11.4	19.7	331
2.5	16.2	149.6	10.7	18.6	320
3.0	16.5	146.9	10.6	19.4	312
3.5	17.4	M	behind stack	19.8	303
4.0	18.0	140.1	10.2	17.9	298
4.5	17.8	137.8	10.2	17.9	297
5.0	17.4	135.2	10.2	18.0	293
5.5	17.2	133.2	10.2		
6.0	17.0	behind trailer			
6.5	16.6				
7.0	16.2				
7.5	15.8				
8.0	15.3				
8.5	14.8				
9.0	14.2				
9.5	13.7				
10.0	13.4				
10.5					
11.0					
11.5					

MINISONDE		THEODOLITE NO. 1		THFODOLITE NO. 2	
TEMP	TEMP. °C	AZIMUTH	ELEVATION	AZIMUTH	ELEVATION
12.5					
13.0					
13.5					
14.0					
14.5					
15.0					
15.5					
16.0					
16.5					
17.0					
17.5					
18.0					
18.5					
19.0					
19.5					
20.0					
20.5					
21.0					
21.5					
22.0					
22.5					
23.0					
23.5					
24.0					
24.5					
25.0					
25.5					
26.0					

MINISONDE DATA SHEET

PROJECT NO. Alta. Envt. Crossfield NAME: MS11

DATE: 14 Aug. 83 TIME OF RELEASE: 0831 MST

CHART SPEED: _____ TEMP. SPAN: _____ OBSERVER: _____

RH 60.6%

CALIBRATION TEMP: _____ RELEASE TEMP: 19.4°C OBSERVER: _____

BASELINE DIRECTION: _____ PLUME OBS. 1 2 3 4 5 6 7 8 9

COMMENTS: 5/10 AC 3/10 SC strong N winds shaking the trailer

MINISONDE		THEODOLITE NO. 1		WIND	
TIME	TEMP. °C	AZIMUTH	ELEVATION	SPEED (M/S)	DIRECTION
0.0	19.4				
0.5	17.7	172.6	13.7	13.5	352
1.0	16.3	173.3	12.5	16.4	353
1.5	15.8	172.1	11.3	19.8	349
2.0	15.2	170.8	10.2	20.5	347
2.5	14.6	169.8	9.9	20.5	346
3.0	14.4	169.0	9.5	22.6	346
3.5	14.3	168.6	9.1	22.8	348
4.0	13.8	168.8	8.9	21.7	348
4.5	13.5	168.4	8.8	18.1	347
5.0	13.4	168.6	9.0	17.0	351
5.5	12.7	168.8	9.0	18.9	350
6.0	12.5	168.9	9.0	18.9	349
6.5	12.3	168.8	9.0	20.5	345
7.0	12.3	168.3	8.9	24.1	340
7.5	12.8	167.4	8.7	18.4	329
8.0	14.1	166.0	9.0		
8.5	15.0	lost			
9.0	15.0				
9.5	14.9				
10.0	14.4				
10.5					
11.0					
11.5					

MINISONDE		THEODOLITE NO. 1		THFODOLITE NO. 2	
TEMP	TEMP. °C	AZIMUTH	ELEVATION	AZIMUTH	ELEVATION
12.5					
13.0					
13.5					
14.0					
14.5					
15.0					
15.5					
16.0					
16.5					
17.0					
17.5					
18.0					
18.5					
19.0					
19.5					
20.0					
20.5					
21.0					
21.5					
22.0					
22.5					
23.0					
23.5					
24.0					
24.5					
25.0					
25.5					
26.0					

MINISONDE DATA SHEET

PROJECT NO. Alta. Envt. Crossfield NAME: MS12

DATE: 14 Aug. 83 TIME OF RELEASE: 1342 MST

CHART SPEED: _____ TEMP. SPAN: _____ OBSERVER: _____

RH 41.8 %

CALIBRATION TEMP: _____ RELEASE TEMP: 24.5°C OBSERVER: _____

BASELINE DIRECTION: _____ PLUME OBS. 1 2 3 4 5 6 7 8 9

COMMENTS: 3/10 mare's tail 2/10 SC to NW moderate gusts

MINISONDE		THEODOLITE NO. 1		WIND	
TIME	TEMP. °C	AZIMUTH	ELEVATION	SPEED (M/S)	DIRECTION
0.0	24.5				
0.5	20.5	182.9	35.4	5.2	3
1.0	19.0	181.9	29.4	7.5	2
1.5	18.2	182.4	25.1	9.7	3
2.0	17.7	182.8	21.8	10.9	7
2.5	17.2	185.2	20.1	12.2	13
3.0	16.9	187.4	18.4	11.2	17
3.5	16.3	189.0	18.4	8.9	18
4.0	15.7	190.0	18.5	8.6	15
4.5	15.1	190.2	18.6	7.2	8
5.0	14.3	189.6	19.2	5.5	6
5.5	13.6	189.7	19.9	6.2	16
6.0	12.8	190.5	20.1	7.6	32
6.5	12.8	192.9	20.3		
7.0	13.0	lost			
7.5	13.0				
8.0	13.4				
8.5	13.7				
9.0	13.2				
9.5	12.7				
10.0	12.2				
10.5					
11.0					
11.5					

MINISONDE		THEODOLITE NO. 1		THFODOLITE NO. 2	
TEMP	TEMP. °C	AZIMUTH	ELEVATION	AZIMUTH	ELEVATION
12.5					
13.0					
13.5					
14.0					
14.5					
15.0					
15.5					
16.0					
16.5					
17.0					
17.5					
18.0					
18.5					
19.0					
19.5					
20.0					
20.5					
21.0					
21.5					
22.0					
22.5					
23.0					
23.5					
24.0					
24.5					
25.0					
25.5					
26.0					

MINISONDE DATA SHEET

PROJECT NO. Alta. Envt. Crossfield NAME: MS13

DATE: 15 Aug. 83 TIME OF RELEASE: 0739 MST

CHART SPEED: _____ TEMP. SPAN: _____ OBSERVER: _____

CALIBRATION TEMP: _____ RELEASE TEMP: 14.3 OBSERVER: _____

BASELINE DIRECTION: _____ PLUME OBS. 1 2 3 4 5 6 7 8 9

COMMENTS: cool overnight; Calgary minimum of 4°C
moderate to strong S gusts; scattered SC to W horizon less than 1/10

MINISONDE		THEODOLITE NO. 1		WIND	
TIME	TEMP. °C	AZIMUTH	ELEVATION	SPEED (M/S)	DIRECTION
0.0	14.3				
0.5	13.7	343.1	14.4	14.4	165
1.0	13.0	346.9	11.8	18.3	172
1.5	12.5	349.1	10.6	20.8	172
2.0	12.4	349.4	9.7	22.3	169
2.5	11.9	349.0	9.2	22.4	167
3.0	11.4	348.2	8.9	24.8	166
3.5	11.6	347.9	8.4	26.9	166
4.0	11.6	347.6	8.1	26.2	166
4.5	12.7	347.3	7.9	26.6	165
5.0	12.4	347.1	7.7	26.4	167
5.5	12.3	347.3	7.6	24.0	172
6.0	12.4	348.0	7.6	22.9	179
6.5	12.7	349.2	7.6	19.1	185
7.0	14.3	350.2	7.8	15.0	192
7.5	13.9	351.3	8.0	14.5	197
8.0	13.7	352.1	8.2	9.7	201
8.5	13.3	352.9	8.6	5.4	241
9.0	12.8	353.8	9.1	5.3	85
9.5	11.9	354.7	9.6		
10.0	11.1	lost			
10.5					
11.0					
11.5					

MINISONDE		THEODOLITE NO. 1		THFODOLITE NO. 2	
TEMP	TEMP. ^{o}C	AZIMUTH	ELEVATION	AZIMUTH	ELEVATION
12.5					
13.0					
13.5					
14.0					
14.5					
15.0					
15.5					
16.0					
16.5					
17.0					
17.5					
18.0					
18.5					
19.0					
19.5					
20.0					
20.5					
21.0					
21.5					
22.0					
22.5					
23.0					
23.5					
24.0					
24.5					
25.0					
25.5					
26.0					

MINISONDE DATA SHEET

PROJECT NO. Alta. Envt. Crossfield NAME: MS14

DATE: 15 Aug. 83 TIME OF RELEASE: 1037 MST

CHART SPEED: _____ TEMP. SPAN: _____ OBSERVER: RDD

CALIBRATION TEMP: 23.2 RELEASE TEMP: 21.4°C OBSERVER: _____

BASELINE DIRECTION: T.N. PLUME OBS. 1 2 3 4 5 6 7 8 9

COMMENTS: ascent rate approximately 230 m/min
1/10 SC buildup along S and W horizon; moderate gusty S wi
at surface

MINISONDE		THEODOLITE NO. 1		WIND	
TIME	TEMP. °C	AZIMUTH	ELEVATION	SPEED (M/S)	DIRECTION
0.0	21.4				
0.5	18.5	355.3	28.7	6.5	175
1.0	16.7	358.6	30.6	5.5	175
1.5	15.4	352.1	32.6	7.7	163
2.0	16.0	351.2	28.5	10.8	174
2.5	17.4	354.6	25.9	11.3	186
3.0	16.6	357.8	24.5	10.3	190
3.5	15.7	359.5	24.2	9.0	190
4.0	15.1	1.0	24.2	8.0	194
4.5	14.2	2.6	24.6	7.8	202
5.0	13.4	4.9	24.8	7.8	208
5.5	12.7	6.9	25.2	6.2	222
6.0	11.4	9.4	26.3	6.1	232
6.5	10.1	12.0	26.8	7.5	235
7.0	8.8	15.3	27.3	7.5	241
7.5	7.6	17.9	27.8	7.1	246
8.0	6.1	20.9	28.4	8.6	244
8.5	5.2	23.9	28.2	10.6	245
9.0	4.1	27.5	28.1	11.6	250
9.5	3.3	30.8	27.7	12.4	250
10.0	2.3	33.9	27.3	12.7	256
10.5	1.1				
11.0	0.0				

MINISONDE		THEODOLITE NO. 1		THEODOLITE NO. 2	
TEMP	TEMP. °C	AZIMUTH	ELEVATION	AZIMUTH	ELEVATION
12.5					
13.0					
13.5					
14.0					
14.5					
15.0					
15.5					
16.0					
16.5					
17.0					
17.5					
18.0					
18.5					
19.0					
19.5					
20.0					
20.5					
21.0					
21.5					
22.0					
22.5					
23.0					
23.5					
24.0					
24.5					
25.0					
25.5					
26.0					

MINISONDE DATA SHEET

PROJECT NO. Alta. Envt. Crossfield NAME: MS 15

DATE: 17 Aug. 83 TIME OF RELEASE: 0846 MST

CHART SPEED: _____ TEMP. SPAN: _____ OBSERVER: _____

CALIBRATION TEMP: _____ RELEASE TEMP: 18.5°C OBSERVER: _____

BASELINE DIRECTION: _____ PLUME OBS. 1 2 3 4 5 6 7 8 9

COMMENTS: 1/10 Sc to W; moderate to strong gusts from SSW; clear overhead

MINISONDE		THEODOLITE NO. 1		WIND	
TIME	TEMP. °C	AZIMUTH	ELEVATION	SPEED (M/S)	DIRECTION
0.0	18.5				
0.5	15.4	1.5	30.5	7.1	185
1.0	15.5	5.6	23.0	8.5	191
1.5	14.9	8.6	22.2	9.9	199
2.0	17.1	14.8	19.7	11.8	211
2.5	18.1	M		12.7	217
3.0	18.1	24.7	17.3		
3.5	17.8	lost			
4.0	17.3				
4.5	16.8				
5.0	16.3				
5.5	15.9				
6.0	15.4				
6.5	15.0				
7.0	14.4				
7.5	13.9				
8.0	13.4				
8.5	12.7				
9.0	12.0				
9.5	11.2				
10.0	10.4				
10.5					
11.0					
11.5					

MINISONDE		THEODOLITE NO. 1		THFODOLITE NO. 2	
TEMP	TEMP. °C	AZIMUTH	ELEVATION	AZIMUTH	ELEVATION
12.5					
13.0					
13.5					
14.0					
14.5					
15.0					
15.5					
16.0					
16.5					
17.0					
17.5					
18.0					
18.5					
19.0					
19.5					
20.0					
20.5					
21.0					
21.5					
22.0					
22.5					
23.0					
23.5					
24.0					
24.5					
25.0					
25.5					
26.0					